FIG. 1

100

SOURCE PROGRAM — 110

↓

LEXICAL ANALYSIS — 120

↓

SYNTAX ANALYSIS — 130

↓

INTERMEDIATE CODE GENERATION — 140

↓

CODE OPTIMIZATION — 150

↓

CODE GENERATION — 160

↓

TARGET PROGRAM — 170

FIG. 2

200

SOURCE CODE LANGUAGE 1 — 205

SOURCE CODE LANGUAGE 2 — 206

SOURCE CODE LANGUAGE 3 — 207

SOURCE CODE LANGUAGE 4 — 208

IL1 — 210

IL2 — 211

IL3 — 212

IL4 — 213

IL READER — 220

LANGUAGE INDEPENDENT INTERMEDIATE REPRESENTATION — 230

COMPILER BACK END — 240

FIG. 3A

300

RECEIVE AN INTERMEDIATE LANGUAGE REPRESENTATION OF A SOURCE CODE FILE — 310

READ OR PARSE THE INTERMEDIATE LANGUAGE REPRESENTATION — 315

IDENTIFY EXCEPTION HANDLING CLAUSES AND OPERATIONS WITHIN THE INTERMEDIATE LANGUAGE REPRESENTATION — 320

TRANSLATE THE IDENTIFIED CLAUSES AND OPERATIONS INTO A SINGLE UNIFORM REPRESENTATION REGARDLESS OF THE SOURCE LANGUAGE — 330

FIG. 3B

350

READ THE UNIFORM INTERMEDIATE REPRESENTATION OF THE SOFTWARE — 360

GENERATE COMPUTER-EXECUTABLE VERSION OF THE SOFTWARE — 370

FIG. 4

460 — COMPILER BACK END

450 — LANGUAGE INDEPENDENT INTERMEDIATE REPRESENTATION

435 — CIL READER

445 — MSIL READER

430 — CIL

440 — MSIL

C++ FRONT END

420 — STRUCTURED EXCEPTION HANDLING (SEH)

C#

MICROSOFT VISUAL BASIC

410 — JSCRIPT

C

FORTRAN

FIG. 5

Gregory L. Maurer, Klarquist Sparkman, LLP, 121 SW Salmon St., Suite 1600, Portland, Oregon 97204,
(503) 226-7391; Inventor: Grover et al.; Title: AN INTERMEDIATE REPRESENTATION FOR
MULTIPLE EXCEPTION HANDLING MODELS; Attorney Docket No.: 3382-65591;
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FIG. 6

```
void foo(int a, int b, int c, int d)
{
   x = a div b;
   x = c div d;
}
```

FIG. 7

```
    a.int32, b.int32, c.int32 d.int32 = ENTER foo
    x.int32 = DIV a.int32, b.int32; $HANDLER
    x.int32 = DIV c.int32, d.int32; $HANDLER        710
    EXIT
$HANDLER:
    UNWIND
    EXIT
```

FIG. 8

```
void foo(int a, int b, int c, int d)
{
  try
  {                        810
    x = a + b;
    x = x + c * d;
  }
  finally        815
  {
    x = x + 1;
  }
}
```

FIG. 9

```
    a.int32, b.int32, c.int32 d.int32 = ENTER foo
    x.int32 = ADD a.int32, b.int32;        910
    t.int32 = MUL c.int32, d.int32;
    x.int32 = ADD x.int32, t.int32;
    FINAL $FINALIZE, $END         915
$FINALIZE:                        920
    e.obj32, r.code = FINALLY;
    x.int32 = ADD x.int32, 1.int32;
    ENDFINALLY e.obj32, r.code, $END;
$END:
    EXIT;
```

FIG. 10

```
void foo(int a, int b, int c, int d)
{
   try
   {
     x = a div b;
     x = c div d;        1010
   }
   finally        1015
   {
     x = x + 1;
   }
}
```

FIG. 11

```
      a.int32, b.int32, c.int32 d.int32 = ENTER foo
      x.int32 = DIV a.int32, b.int32; $FINALIZE
      x.int32 = DIV c.int32, d.int32; $FINALIZE       1110
      FINAL $FINALIZE, $END     1112
$FINALIZE:
      e.obj32, r.code = FINALLY;     1115
      x.int32 = ADD x.int32, 1.int32;
      ENDFINALLY e.obj32, r.code, $END; $PROPAGATE     1120
$END:
      EXIT;
$PROPAGATE:
      UNWIND
      EXIT;
```

Gregory L. Maurer, Klarquist Sparkman, LLP, 121 SW Salmon St., Suite 1600, Portland, Oregon 97204,
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FIG. 12

1240

```
1    void foo(int a, int b, int c, int d)
2    {
3      try                                    1210
4      {
5      x = a div b;
6      x = c div d;
7      }
8      catch (System.DivideByZeroException f)   1215
9      {
10     b = 1;                                  1220
11     d = 1;
12     }
13     catch (System.Exception e)   1225
14     {
15     bar();                                  1231
16     }
17   }
```

FIG. 13

```
a.int32, b.int32, c.int32 d.int32 = ENTER foo
x.int32 = a.int32 DIV b.int32; $HANDLER1
x.int32 = c.int32 DIV d.int32; $HANDLER1        1310
GOTO $END$
$HANDLER1:                                       1315
    F.DivideByZeroException = TYPEFILTER $CATCH1,
HANDLER2;
$CATCH1:                                         1320
    b.int32 = ASSIGN 1.int32;
    d.int32 = ASSIGN 1.int32;
    GOTO $END
$HANDLER2:                                       1325
    E.Exception = TYPEFILTER $CATCH2, $PROPAGATE;
$CATCH2:                          1330
    CALL bar(); $PROPAGATE
    GOTO $END
$PROPAGATE:
    UNWIND   1335
    EXIT;
```
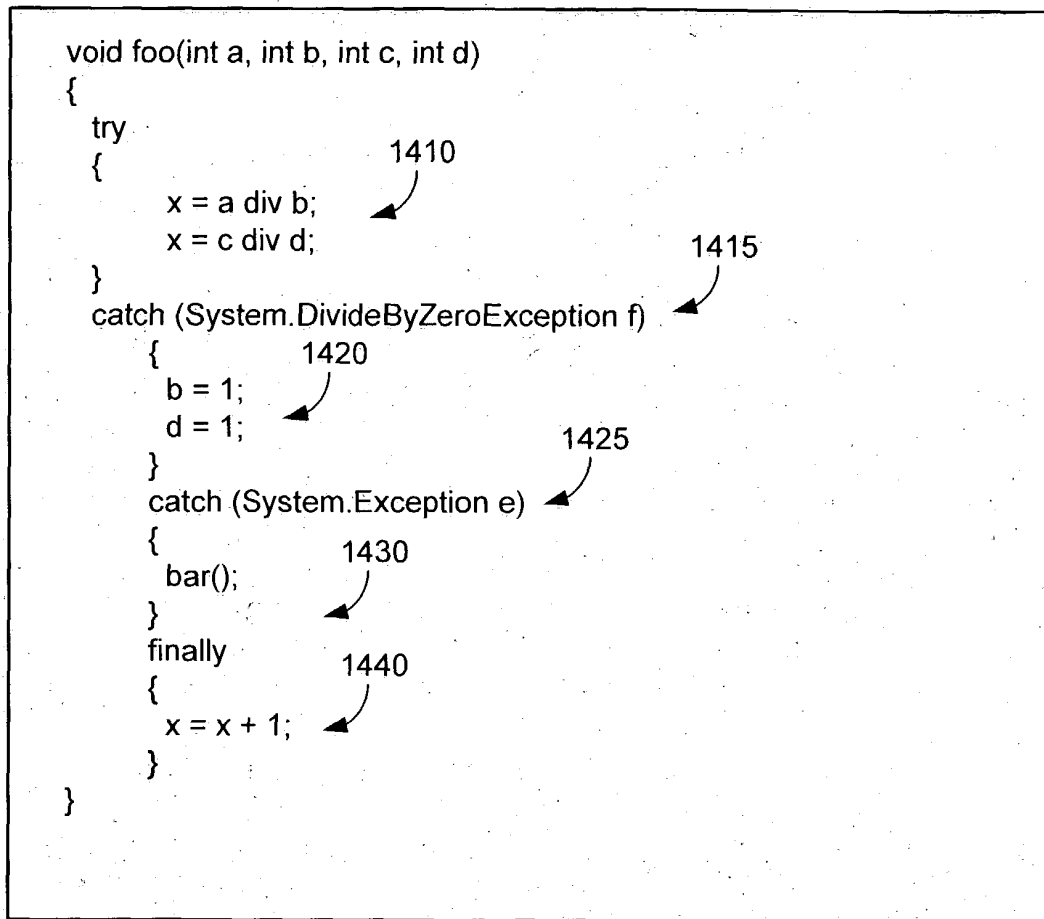
FIG. 14

```
void foo(int a, int b, int c, int d)
{
  try
  {                        1410
      x = a div b;
      x = c div d;                          1415
  }
  catch (System.DivideByZeroException f)
      {           1420
        b = 1;
        d = 1;                   1425
      }
      catch (System.Exception e)
      {           1430
        bar();
      }
      finally      1440
      {
        x = x + 1;
      }
}
```

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FIG. 15

```
a.int32, b.int32, c.int32 d.int32 = ENTER foo
    x.int32 = a.int32 DIV b.int32; $HANDLER1 ⟩ 1510
    x.int32 = c.int32 DIV d.int32; $HANDLER1
    FINAL $FINALIZE, $END
$HANDLER1:
    F.DivideByZeroException = TYPEFILTER $CATCH1, ~1515
$HANDLER2;
$CATCH1:                                    1520
    b.int32 = ASSIGN 1.int32;
    d.int32 = ASSIGN 1.int32;
    FINAL $FINALIZE, $END; ~1521
$HANDLER2:
    E.Exception = TYPEFILTER $CATCH2, $FINALIZE; ~1525
$CATCH2:                                    1530
    CALL bar(); $FINALIZE
    FINAL $FINALIZE, $END ~1531
$FINALIZE:
    e.obj32, r.code = FINALLY;               1540
    x.int32 = ADD x.int32, 1.int32;
    ENDFINALLY e.obj32, r.code, $END; $PROPAGATE
$PROPAGATE:  1550
    UNWIND
    EXIT;       1560
$END:
    EXIT;
```
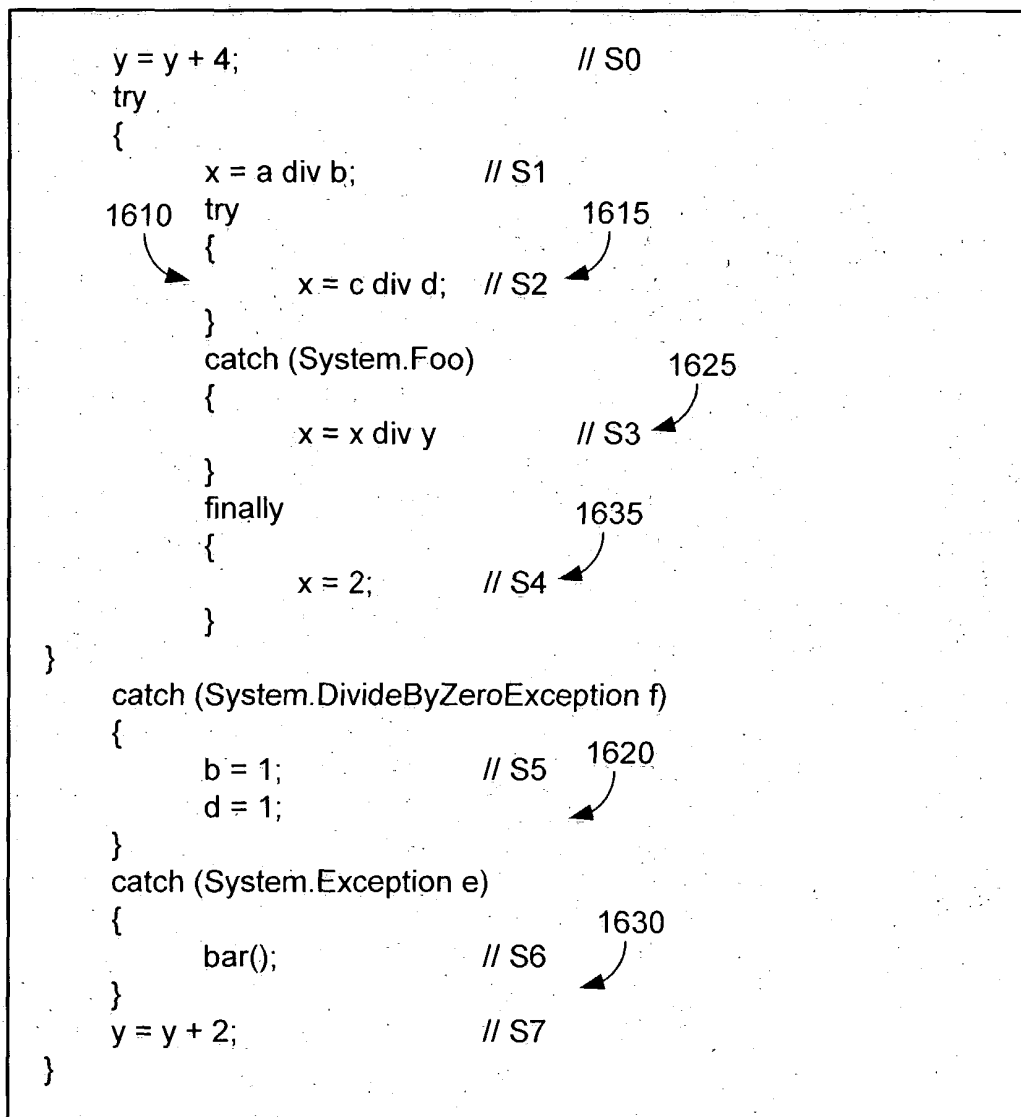
FIG. 16

```
y = y + 4;                            // S0
try
{
        x = a div b;          // S1
1610    try                              1615
        {
                x = c div d;   // S2
        }
        catch (System.Foo)               1625
        {
                x = x div y          // S3
        }
        finally                          1635
        {
                x = 2;          // S4
        }
}

catch (System.DivideByZeroException f)
{
        b = 1;                   // S5    1620
        d = 1;
}
catch (System.Exception e)
{                                        1630
        bar();                   // S6
}
y = y + 2;                      // S7
}
```

FIG. 17

```
    y.int32 = ADD y.int32, 1.int32                        // S0
    x.int32 = a.int32 DIV b.int32; $HANDLER1   1705       // S1
    x.int32 = c.int32 DIV d.int32; $HANDLER3   1706       // S2
    FINAL $FINALIZE, $S7;
$FINALIZE:                        1725
    e0, r0 = FINALLY
    x.int32 = ASSIGN 2.int32;                             // S4
    ENDFINALLY e0, r0, $S7; $HANDLER1   1726
$HANDLER3:
    e1 = TYPEFILTER $CATCH3, $FINALIZE
$CATCH3:
    x.int32 = DIV x.int32, y.int32; $FINALIZE   1720      // S3
    FINAL $FINALIZE, $S7;   1710
$HANDLER1:
    e2 = TYPEFILTER $CATCH1, $HANDLER2;
$CATCH1:
    b.int32 = ASSIGN 1.int32;                             // S5
    d.int32 = ASSIGN 1.int32;
    GOTO $S7;          1715
$HANDLER2:
    e3 = TYPEFILTER $CATCH2, $PROPAGATE;
$CATCH2:
    CALL bar(); $PROPAGATE;                               // S6
    GOTO $S7
$PROPAGATE:
    UNWIND
    EXIT;
$S7:
    y.int32 = ADD y.int32, 1.int32                        // S7
    GOTO $END;
$END:
    EXIT;
```

FIG. 18

FIG. 19A

ENTRY	INFO TAG ⌐1915	PROTECTED BLOCK ⌐1910	DESTINATION/HANDLER BLOCK ⌐1920
1	TRY CATCH	3-7	8-12
2	TRY CATCH	3-7	13-16

FIG. 19B

DESTINATION/HANDLER BLOCK OFFSET	LABEL
8-12	HANDLER 1
13-16	HANDLER 2

FIG. 19C

PROTECTED BLOCK OFFSET	DESTINATION/HANDLER BLOCK OFFSET	LABEL
3-7	8-12	HANDLER 1
3-7	13-16	HANDLER 2

FIG. 20

FIG. 21

FIG. 22

```
void proc()
{
   class1 obj1;  // S1
   obj1.foo();  // S2
   class2 obj2;  // S3
   obj2.bar();  // S4
}
```

FIG. 23

```
void proc()
{                          2310
    ctor1(&obj1);
    try
    {
      obj1.foo();
      ctor2(&obj2);
          try
          {                    2330
               obj2.bar();
          }
          finally
          {                      2340
               dtor2(&obj2);
          }
    }
    finally
    {                      2320
          dtor1(&obj1)
    }
}
```

FIG. 24

```
ENTER proc
CALL class1, &_obj1   $PROPAGATE
CALL foo, &_obj1 $DTOR1
CALL class1,&_obj2 $DTOR1
CALL bar, &_obj2 $DTOR2
FINAL $DTOR2, $NEXT;          ~2410
$NEXT:
    FINAL $DTOR1, $END        ~2420
$DTOR2:
    e, r = FINALLY
    CALL DTOR2(&obj2); $DTOR1  ~2435     2430
    ENDFINALLY e, r, $DTOR1, $NEXT
$DTOR1:
    e2, r2 = FINALLY                        2440
    CALL DTOR1(&obj1); $PROPAGATE  ~2445
    ENDFINALLY e1, r2, $PROPAGATE, $END
$PROPAGATE:
    UNWIND
    EXIT;
$END:
    EXIT;
```

FIG. 25

```
void proc(int x)
{
    foo(x ? obj1(x) : obj2(x+1));
}
```

FIG. 26

```
void proc()
{
    try
    {
      t1 = x ? ctor(&obj1,x) : NULL;        2610
      try
      {
         t2 = x ? NULL : ctor(&obj2,x+1)    2620
         foo( x  ? t1 : t2);
      }
      finally
      {
          if (x) dtor(&obj1);               2630
      }
    }
    finally
    {
      if (!x) dtor(&obj2);                  2640
    }
}
```

FIG. 27

```
    _x              =       ENTER proc
    t140            =       CMP(NE) _x, 0
                            CBRANCH(NE) t140, $L4, $L5 ~~2710

    $L4:
        t134        =       CALL ctor, &objl, _x; $PROPAGATE
2720    t135        =       ASSIGN t134                    2721
        tv141-      =       ASSIGN [t135)
        $t142       =       ASSIGN 1
                            GOTO $L6

    $L5:
        t137        =       ADD _x, 1                      2731
2730    t138        =       CALL ctor, &obj2, t137; $PROPAGATE
        t139        =       ASSIGN t138
        tv141-      =       ASSIGN [t139)
        $t142       =       ASSIGN 0
                            GOTO $L6

    $L6:
        t145        =       ASSIGN tv141-
                            CALL bar, t145
                            FINAL $OBJ1, $L11

    $L11:
                            FINAL $OBJ2, $L12

    $OBJ1:
        r1          =       FINALLY
        t144        =       CMP(EQ) $t142, 0
                            CBRANCH(EQ) t144, $L9, $L10

    $L9:
                            CALL dtor, &objl $PROPAGATE
                            GOTO $L10

    $L10:   2740            ENDFINALLY; rl, [$L11), $PROPAGATE

    $OBJ2:
        r2          =       FINALLY
        t143        =       CMP(EQ) $t142, 1
                            CBRANCH(EQ) t143, $L7, $L8

    $L7:
                            CALL dtor, &obj2 $PROPAGATE
                            GOTO $L8

    $L8:    2750            ENDFINALLY; r2, [$L12), $PROPAGATE

    $PROPAGATE:
                            UNWIND
                            EXIT
    $L12:
                            EXIT
```

FIG. 28

```
Obj foo(int x)
 {
   Obj a , b;        2810
   bar();
   if (x == 0)
   {
     return Obj(1);   2820
   }
   else
   {
     return Obj(2);   2830
   }
 }
```

FIG. 29A

```
Obj foo(int x)
    {
    CALL ctor (&a); $unwind;
    CALL ctor (&b); $final_a;
    bar(); $final_b;
    if (x == 0)
    {
        CALL ctor Obj (&r1,1) ; $final_b;        ~2960
        $f1 = 1;        ~2950
        FINAL $final_b1; L2
        L2:
          FINAL $final_a1, L1
        L1:
          $f1 = 0;
          FINAL $final_r1, Lret
        Lret:
          return r1;        ~2910
    }
    CALL ctor Obj(&r2, 2); $final_b;
    $f2 = 1;
    FINAL $final_b2, L3
    L3:
      FINAL $final_a2, L4
    L4:
      $f2 = 0;
      FINAL $final_r2, Lret2
    Lret2:
      return r2;
```

FIG. 29B

```
$final_b:
        e, R = FINALLY
        DTOR (&b); $final_a;
        ENDFINALLY e, R, $final_a;
    $final_a:
        e, R = FINALLY
        CALL DTOR (&a); $unwind;
        ENDFINALLY e, R, HANDLER:$unwind;
    $final_b1:
        e, R = FINALLY
        CALL DTOR (&b); $final_a1;        ~2930
        ENDFINALLY e, R, [L2], $final_a1;
    $final_a1:
        e, R = FINALLY
        CALL DTOR (&a); $final_r1;        ~2920
        ENDFINALLY e, R, [L1]; $final_r1;
    $final_b2:
        e, R = FINALLY
        CALL DTOR (&b); $final_a2;
        ENDFINALLY e, R,[L3]; $final_a2;
    $final_a2:
        e, R = FINALLY
        CALL DTOR (&a); $final_r2;
        ENDFINALLY e, R, [L4]; $final_r2;
    $final_r1:
        e, R = FINALLY
        if ($f1 == 1) CALL DTOR (&r1);$unwind;   ~2940
        ENDFINALLY e, R, [Lret1]; $unwind;
    $final_r2:
        e, R = FINALLY
        if ($f2 == 1) CALL DTOR (&r2); $unwind;
        ENDFINALLY e, R,[Lret2]; $unwind;
    }
```

Gregory L. Maurer, Klarquist Sparkman, LLP, 121 SW Salmon St., Suite 1600, Portland, Oregon 97204,
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FIG. 30

```
void proc()
{
    class1 obj1; // S1 - create an obj of type Class1
    obj1.foo();  // S2 - calling a method on obj.1
    throw foo;   // S3
}
```

FIG. 31

```
void proc()
{
    class1 obj1;                                        // S1
    class1 temp;
    try {
        obj1.foo();                    3110             // S2
            temp.copy_ctor(obj1);//
            special_throw(&temp, &dtor_of_class1)    // S3
    }                                                      3120
    finally {
        dtor_of_class1(obj1);
    }                              3130
}
```

FIG. 32

```
    ENTER proc
    CALL ctor1(&obj1); $PROPAGATE
    CALL foo(&obj1);   $DTOR1
    CALL copy_ctor(&temp, &obj1); $DTOR1
    FINAL $DTOR1;
    THROWVAL &temp, &dtor_of_class1; $PROPAGATE
$DTOR1:              3220           3230            3210
    e2, r2 = FINALLY
    CALL DTOR1(&obj1); $PROPAGATE
    ENDFINALLY e1, r2, $PROPAGATE, $END
$PROPAGATE:
    UNWIND
    EXIT;
$END:
    EXIT;
```

FIG. 33

```
void proc()
{
    __try {
        foo();
    } __except(filter()) {
        body();
    }
    next();
}
```

Gregory L. Maurer, Klarquist Sparkman, LLP, 121 SW Salmon St., Suite 1600, Portland, Oregon 97204,
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FIG. 34

```
    ENTER proc
$LABEL:
    SEHENTER;    $HANDLER ~3410
    CALL foo();   $HANDLER ~3420
    GOTO $NEXT;
$HANDLER: ~3430
    x = FILTER
    t = CALL filter(); ~3450
    ENDRESUMEFILTER t, $HANDLERBODY, $END, $LABEL
$HANDLERBODY:                                      ~3440
    CALL body(); $PROPAGATE
    GOTO $NEXT;
$NEXT:
    CALL next();
    EXIT;
$END:
    EXIT;
```
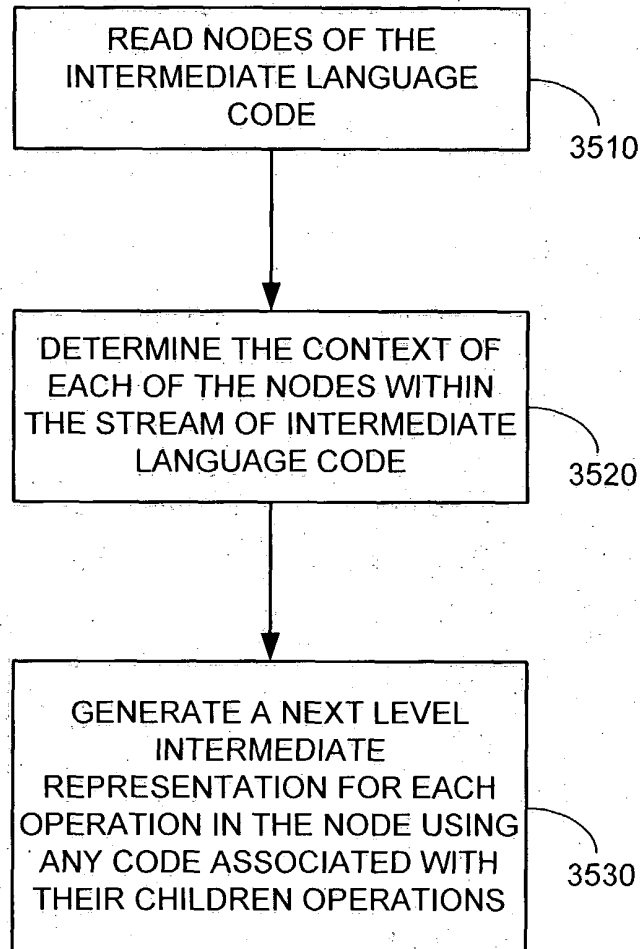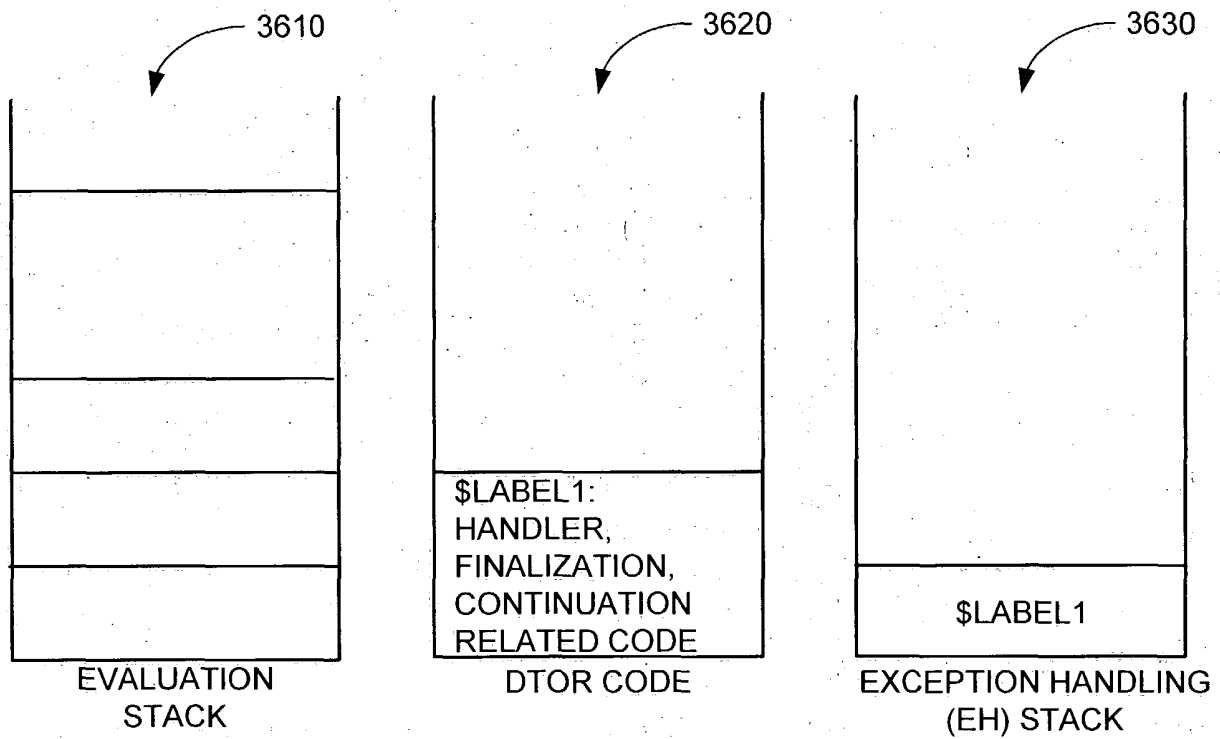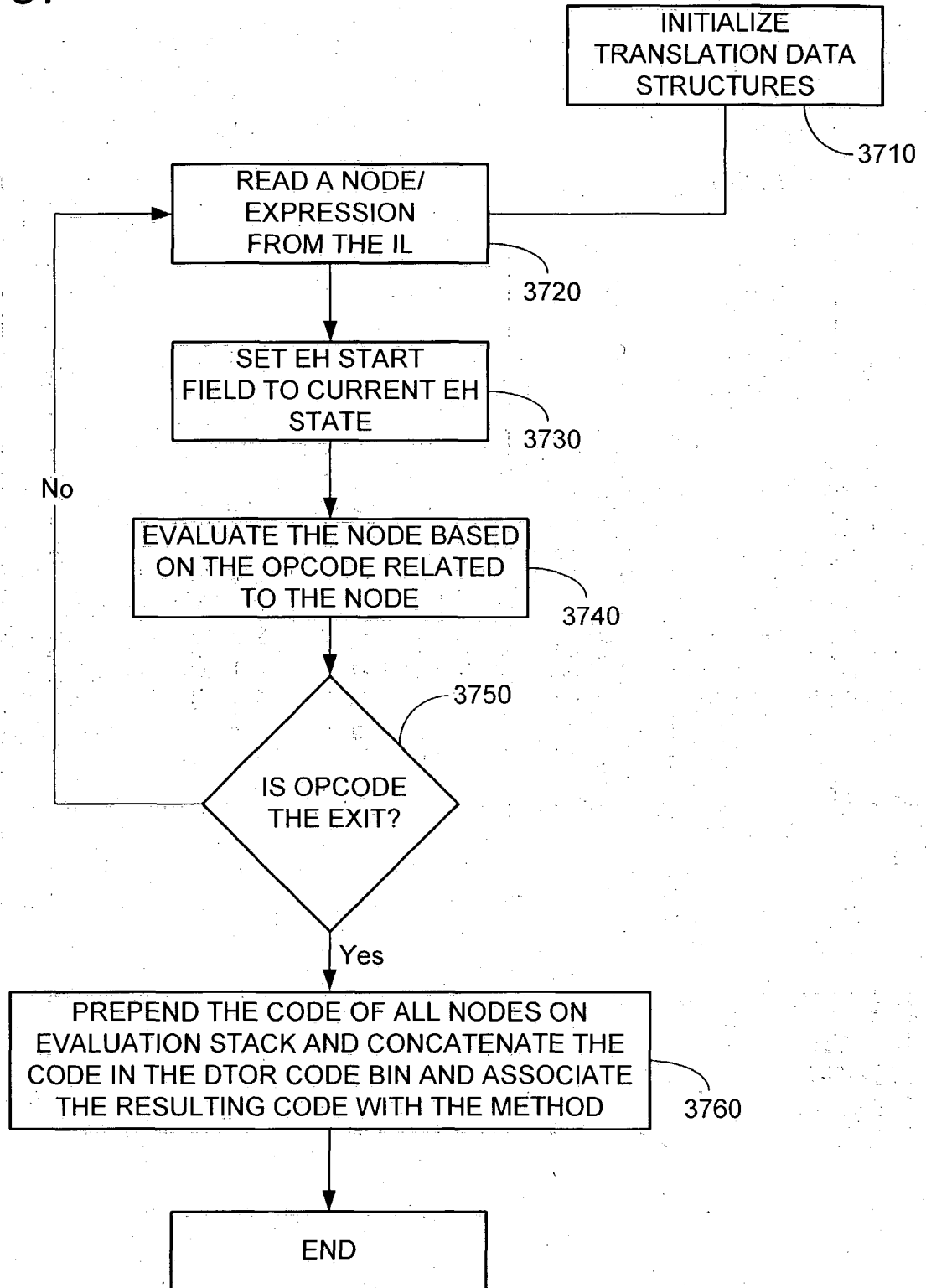
FIG. 35

READ NODES OF THE INTERMEDIATE LANGUAGE CODE

3510

DETERMINE THE CONTEXT OF EACH OF THE NODES WITHIN THE STREAM OF INTERMEDIATE LANGUAGE CODE

3520

GENERATE A NEXT LEVEL INTERMEDIATE REPRESENTATION FOR EACH OPERATION IN THE NODE USING ANY CODE ASSOCIATED WITH THEIR CHILDREN OPERATIONS

3530

FIG. 36

3610

3620

3630

EVALUATION
STACK

$LABEL1:
HANDLER,
FINALIZATION,
CONTINUATION
RELATED CODE

DTOR CODE

$LABEL1

EXCEPTION HANDLING
(EH) STACK

FIG. 37

INITIALIZE TRANSLATION DATA STRUCTURES
— 3710

READ A NODE/ EXPRESSION FROM THE IL
3720

SET EH START FIELD TO CURRENT EH STATE
3730

EVALUATE THE NODE BASED ON THE OPCODE RELATED TO THE NODE
3740

3750

IS OPCODE THE EXIT?

No

Yes

PREPEND THE CODE OF ALL NODES ON EVALUATION STACK AND CONCATENATE THE CODE IN THE DTOR CODE BIN AND ASSOCIATE THE RESULTING CODE WITH THE METHOD
3760

END

FIG. 38A

```
>>> IL for function ?proc@@YAXXZ:
OPpragma pragma(31)    PR_PRAGSTAT Pragma Status: 0x00800000
OPpragma pragma(32)    PR_INLINE Inline Status: 0x0010
OPpragma pragma(2)     PR_FILENAME Filename key(0x20)
OPpragma pragma(1)     PR_LINENUMBER Line(22)
OPpragma pragma(35)    PR_WARNING 10:OFF; 16:ERR; 72:ERR; 86:OFF;
93:OFF; 120:OFF; 205:OFF; 206:OFF; 217:OFF; 228:OFF; 231:OFF; 246:OFF;
OPblock
OPblock
OPname(?proc@@YAXXZ) symbol(0x288)
OPentry
OPeolist
***** function entry says proc has no parameters ********


**** ctor call for class1 ******************************
OPblock
OPpragma pragma(1)      PR_LINENUMBER Line(23)
OPname(??0class1@@QAE@XZ) symbol(0x25f)              3810
OPname(obj1) symbol(0x28a)
OPconstant integer size(4) align(3) constant(0|0x0)
OPfield address size(4) align(3)
OPconstant integer size(4) align(3) constant(0|0x0)
OPfield address size(4) align(3) Const
OPextract address size(4) align(3) Const
OPmfunc address size(4) align(3)
OPfunction address size(4) align(3) Const functype(20)
OPeolist
******** ********************************


*** dtor call for class1 ******************************
OPname(??1class1@@QAE@XZ) symbol(0x260)
OPname(obj1) symbol(0x28a)                            3820
OPconstant integer size(4) align(3) constant(0|0x0)
OPfield address size(4) align(3)
OPconstant integer size(4) align(3) constant(0|0x0)
OPfield address size(4) align(3) Const
OPextract address size(4) align(3) Const
OPmfunc address size(4) align(3)
OPfunction void size(0) align(1) functype(20)
OPeolist
**********************************************************
```

FIG. 38B

```
OPpushstate address size(4) align(3) EH Flags 0x00000011


                                                          3830

OPexpression
OPpragma pragma(1)       PR_LINENUMBER Line(24)
OPname(?foo@class1@@QAEXXZ) symbol(0x261)
OPname(obj1) symbol(0x28a)
OPconstant integer size(4) align(3) constant(0|0x0)
OPfield address size(4) align(3)
OPconstant integer size(4) align(3) constant(0|0x0)
OPfield address size(4) align(3) Const
OPextract address size(4) align(3) Const
OPmfunc address size(4) align(3)
OPfunction void size(0) align(1) functype(20)
OPeolist
OPexpression
OPpragma pragma(1)       PR_LINENUMBER Line(25)
OPname(??0class2@@QAE@XZ) symbol(0x274)
OPname(obj2) symbol(0x28b)
OPconstant integer size(4) align(3) constant(0|0x0)
OPfield address size(4) align(3)
OPconstant integer size(4) align(3) constant(0|0x0)
OPfield address size(4) align(3) Const
OPextract address size(4) align(3) Const
OPmfunc address size(4) align(3)
OPfunction address size(4) align(3) Const functype(20)
OPeolist
OPname(??1class2@@QAE@XZ) symbol(0x275)
OPname(obj2) symbol(0x28b)
OPconstant integer size(4) align(3) constant(0|0x0)
OPfield address size(4) align(3)
OPconstant integer size(4) align(3) constant(0|0x0)
OPfield address size(4) align(3) Const
OPextract address size(4) align(3) Const
OPmfunc address size(4) align(3)
OPfunction void size(0) align(1) functype(20)
OPeolist
```

FIG. 38C

```
OPpushstate address size(4) align(3) EH Flags 0x00000011
OPexpression
OPpragma pragma(1)      PR_LINENUMBER Line(26)
OPname(?bar@class2@@QAEXXZ) symbol(0x276)
OPname(obj2) symbol(0x28b)
OPconstant integer size(4) align(3) constant(0|0x0)
OPfield address size(4) align(3)
OPconstant integer size(4) align(3) constant(0|0x0)
OPfield address size(4) align(3) Const
OPextract address size(4) align(3) Const
OPmfunc address size(4) align(3)
OPfunction void size(0) align(1) functype(20)
OPeolist
OPexpression
OPpragma pragma(1)      PR_LINENUMBER Line(27)
OPdtoraction cnt(2) EH Flags 0x00000031
OPexpression                              3840
OPgoto symbol(0x289)
OPendblock icon(2)
OPlabel symbol(0x289)
OPexit
OPendblock icon(1)
OPendblock icon(0)
```

FIG. 39

3915

$DTOR1
$PROPOGATE

pop

3940

3920

EH STACK

3925

```
$DTOR1:
E2, R2=FINALLY
CALL DTOR1(&OBJ1); $PROPAGATE;
ENDFINALLY E2, R2; $PROPAGATE;
$PROPOGATE:
UNWIND
EXIT
```

3930

DTOR CODE

3905

CTOR
* * *
* * *

opdtoraction

3910

oppushstate

EVALUATION STACK